Aquatic Chemistry/Toxicology in Watershed-Based Water Quality Management Programs

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There is considerable discussion today about implementing the "watershed approach" for point and nonpoint sources of pollutants in a region. There is, however, considerable confusion about what is meant by the "watershed approach" in water quality management. There is even greater confusion on how the watershed approach should be implemented. U.S. EPA (Perciasepe, 1994) has adopted a Watershed Protection Approach which purports to promote integration of water quality problem solutions in surface waters, ground waters and habitats of concern on a watershed basis. According to Perciasepe, the Watershed Protection Approach is an essential priority for U.S. EPA's Water Program, however little guidance is given on how this approach is to be implemented so that it properly addresses the management of real water quality problems-designated use impairment within a watershed without significant waste of public and private funds controlling chemical constituents from point and nonpoint sources that have little or no impact on the designated beneficial uses of waters. This paper summarizes some of the issues that need to be considered in developing a technically valid, cost-effective watershed approach for managing water quality in a region focusing on the importance of properly incorporating aquatic chemistry and aquatic toxicology of chemical constituents that are to be managed in a watershed-based approach.

Implementation of the Watershed Approach

A watershed approach should be adopted where both point and nonpoint source dischargers work with the regulatory agencies to evaluate the real water quality problems in a particular waterbody. After the real water quality problems-use impairment have been identified then the specific source(s) of the specific pollutant form(s) that is responsible for use impairment should be required to control the input of the pollutants to the degree necessary to protect the designated beneficial uses of the waterbody independent of the nature of the source, i.e. point or nonpoint, agriculture, industry or urban, etc.

As discussed by Lee and Jones-Lee (1995a,b), in assessing water quality use impairment it is important not to assume that an exceedance of a water quality criterion or standard represents such a use impairment. U.S. EPA water quality criteria and state standards based on these criteria are designed to protect aquatic life and other beneficial uses under plausible worst-case or near worst-case conditions. It is indeed rare that those conditions occur. This leads to "administrative exceedances" of water quality standards that do not represent real use impairments but instead reflect the inability of the regulatory agencies to develop and implement water quality criteria and standards that will protect uses without significant over-regulation of the chemical constituents in a watershed.

It is important that those responsible for implementing the watershed approach recognize that all sources of a particular type of chemical constituent, such as copper or phosphorus, do not contribute that chemical constituent to the waterbody that impacts designated beneficial uses to the same degree per unit total concentration. Copper from automobile brake linings/pads in urban storm water runoff will be significantly different in its potential impact on receiving water quality than copper from copper sulfate used to control algae in a water supply reservoir or the copper that is used to kill roots that have penetrated a sanitary sewer system. In one case (the brake linings/pads) the copper originates as a metallic element that is unavailable and non-toxic to aquatic life. In the other cases, the specific form of copper (copper sulfate) is designed to be highly toxic to plant life. Before it is assumed that all sources of copper to a waterbody have equal adverse impacts on the beneficial uses of the waterbody proportional to the total concentration of chemical constituents, site-specific studies should be conducted to determine whether this unexpected situation is occurring. These studies would focus on the use of aquatic life toxicity testing using organisms that are known to be highly sensitive to copper.

The assumption that all sources of copper or other chemical constituents are of equal adverse impact is strongly contrary to aquatic chemistry and aquatic toxicology. Based on the authors' experience it will be indeed rare, if ever, that all sources of copper, phosphorus, or for that matter other chemical constituents, will have equal adverse impact per unit total concentration of a chemical constituent on the designated beneficial uses of a waterbody. It is, therefore, important in developing a watershed approach for water quality management to focus pollutant control on those chemical constituents that are actually significantly impairing the designated beneficial uses of the waterbody(s) within and downstream of the watershed. This is the technically valid, cost-effective approach that should be followed in implementing the watershed approach.

Pollutant Versus Chemical Constituent

Significant problems exist today in the water quality management field because of a failure to recognize the difference between *pollutants* and *chemical constituents*. Chemical constituents are any chemicals added to water, irrespective of the impact. Pollutants by tradition and national regulations are those constituents that are present in a water in sufficient concentrations of available/toxic forms for a sufficient duration to adversely impact the designated beneficial uses of the waterbody.

To assume that pollutants and chemical constituents are the same, as is sometimes done, can be and usually is highly wasteful of public and private funds in "water pollution" management programs. This will be especially true as attempts are made to control pollutants from nonpoint sources. In order to determine whether a chemical constituent is a pollutant it is necessary to develop a site-specific understanding of the aquatic chemistry and aquatic toxicology of the chemical constituent of concern as well as the key components of the designated beneficial uses of a waterbody.

Lee and Jones-Lee (1995c) have discussed that every chemical is toxic to aquatic life and man at some concentration and duration of exposure. The primary issue in water *pollution* control from various point and nonpoint sources in a particular watershed is the evaluation of the concentrations of the chemical constituents in the discharge/runoff that are, because of their chemical forms, significantly impacting the designated beneficial uses of the receiving waters for the discharge/runoff. Paulson and Amy (1993) have suggested that thermodynamic models, such as U.S. EPA's MINTEQ model, can be used to determine the toxic forms of chemical constituents in urban storm water runoff. However, such an approach is not technically valid and will, in general, greatly over-estimate the toxic forms of chemical constituents, such as heavy metals, in storm water runoff.

Pollutant Trading

As part of developing the watershed approach there is discussion of "pollutant" trading, where one source of pollutants in a watershed could be controlled to a greater degree at less cost than required based on allowed total maximum daily loads, thereby enabling another source of the same chemical constituent in the same watershed to control the chemical constituent to a lesser degree. There are a number of examples of watershed-based nutrient trading programs that have been and/or are being developed today that have significant technical problems with the way in which the "pollutant" (nutrient) trading has been established.

Hall and Howett (1994) have discussed "pollutant" (nutrient) trading in the Tar-Pamlico River Basin of North Carolina. They point out that rather than requiring point source dischargers to remove nutrients to a greater degree than currently being achieved, that the use of the funds that could be devoted to nutrient control for point source discharges could be used more effectively to control nutrients from nonpoint discharges. However, the Hall and Howett discussion fails to address one of the most important issues in eutrophication management, namely that various sources of nutrients, especially phosphorus from POTWs and agricultural land runoff, contribute algal available phosphorus to a waterbody to a significantly different degree per unit total phosphorus concentration.

This is a common, widespread problem that is occurring today with the implementation of the watershed approach where those responsible for developing such programs fail to properly incorporate reliable evaluation of the aquatic chemistry and aquatic toxicology of the chemical constituents of concern from various sources in a watershed. As discussed by Lee and Jones-Lee (1992), pollutant trading programs should be implemented where it can be shown that each of the sources of chemical constituents which are to be traded contribute chemical constituents in the same specific chemical forms and amounts to the overall waterbody of concern and thereby enable an improvement in the designated beneficial uses to develop to the same degree based on the control of the pollutant of concern from either source to the same degree. This situation will almost never occur for potentially toxic chemical constituents such as heavy metals, organics, nutrients, and other chemical constituents from point and nonpoint sources. It is highly unlikely that it will ever be possible to reliably trade pollution loads between point and nonpoint sources because of the differences in the chemical forms/impacts of most chemical constituents from these two types of sources without extensive pre-trade evaluation of the actual amounts and impacts of chemical constituents from each source of potential concern.

Another potentially significant problem with pollutant trading is that pollutants may adversely impact waterbodies in two overall ways; near the discharge and in the overall waterbody. Pollutant trading, as it is being discussed today, does not adequately consider localized adverse impacts near the discharge point on the beneficial uses of the waterbody. Local impacts on large waterbodies can be quite significant to the public that utilizes the beneficial uses of the waters near the point of discharge. This point is discussed further by Lee and Jones-Lee (1994a) in evaluating the economic aspects of pollutant trading.

Control of Chemical Constituents at Source-Pollution Prevention

One of the frequently advocated components of a watershed management approach is pollution prevention, i.e. the control of chemical constituents at their source. One of the major areas of concern in regulating urban storm water runoff and other sources of chemical constituents for a waterbody is the presence of elevated concentrations of a number of heavy metals and other chemical constituents in the storm water runoff/discharges that are potentially controllable at the source. Copper is one of the elements of greatest concern in urban storm water runoff. Copper and many other heavy metals are present in urban storm water runoff at concentrations considerably above U.S. EPA water quality criteria. It has been found that one of the principal sources of copper is its use in brake linings/pads for some types of automobiles. This has led some to call for copper source control by requiring that the manufacturers of brake linings/pads stop using copper where some other material would be substituted for the copper that is being used today. Numerous studies have shown, however, that the heavy metals, including copper, in urban storm water runoff are not a source of toxicity to aquatic life (see Mangarella, 1992).

There are significant questions, therefore, about whether voluntary or imposed national or regional bans on the use of copper in brake linings/pads is an appropriate best management practice for storm water runoff water pollution control. While adoption of this approach would likely reduce some of the administrative exceedances of copper at some locations, such as for San Francisco Bay, it would not likely address any real water quality problems (use impairment) associated with the presence of copper in storm water runoff to the Bay or its tributaries. Further, since some other material will have to be substituted for copper, concern should be raised on the potential public health and environmental impact of the substitute material.

In formulating a point and nonpoint source chemical constituent control program, it is important to reliably evaluate the aquatic chemistry and aquatic toxicology of the chemical constituents that are to be controlled through best management practices. It is also important to understand that the current suite of structural best management practices, such as detention basins, grassy swales, etc., were not based on a technically valid assessment and that their implementation would solve real water quality problems (Lee and Jones-Lee, 1996). An example of this situation is the use of detention basins where low flow storm waters are retained in a basin for a period of time where large particulate forms of chemical constituents settle out. However, particulate forms of chemical constituents are generally non-toxic and non-available to aquatic life. Detention basins typically do not remove the soluble/toxic forms of chemical constituents. Lee and Jones-Lee (1995c) have discussed the importance of properly selecting best management practices for chemical constituent control in a watershed, including control at the source, so that the control focuses on addressing real water quality problems rather than wasting public and private funds controlling chemical constituents which have little or no impact on the beneficial uses of the waters in the watershed.

Conclusion

Water pollution control programs should be based on a watershed management-based control program in which all chemical constituent sources to a waterbody are reliably evaluated as to their potential impact on the designated beneficial uses of a waterbody. The focus of the watershed approach should be on protection and, where degraded, enhancement of the designated beneficial uses of the waterbody. For aquatic life-related uses, the focus should be on the numbers, types, and characteristics of desirable aquatic organisms. The mechanical approach that is being adopted today in some watershed approaches for water quality management of considering all chemical constituents from all sources of equal impact on the designated beneficial uses per unit total chemical constituent concentration derived from the source is technically invalid. In implementing the watershed approach, proper evaluation of the chemical constituent aquatic chemistry and aquatic toxicology as it may impact the designated beneficial uses of a waterbody must be made in order to avoid waste of public and private funds in controlling chemical constituent inputs that are not adversely impacting water quality within the watershed and downstream thereof.

Pollutant trading should be based on the trading of real pollutants, i.e., those that impact designated beneficial uses at a particular location in a waterbody. Consideration should be given to waterbody-wide effects as well as those that can occur near the point of discharge/runoff.

References

Hall, J.C., and Howett, C.M. (1994). *Trading in the Tar-Pamlico*. Water Environment & Technology, 6(7):58-61.

Lee, G.F., and Jones-Lee, A. (1994a). *Water quality issues in pollutant trading*. Submitted for publication in Water Resource Bulletin.

Lee, G.F. and Jones-Lee, A. (1995a). *Appropriate use of numeric chemical water quality criteria*. Health and Ecological Risk Assessment, 1:5-11.

Lee, G.F. and Jones-Lee, A. (1995b). *Independent applicability of chemical and biological criteria/standards and effluent toxicity testing.* The National Environmental Journal, 5(1):60-63 (1995), *Part II, An alternative approach.* 5(2):66-67.

Lee, G.F. and Jones-Lee, A. (1995c). *Storm water runoff management: Are real water quality problems being addressed by current structural best management practices? Part 1.* Public Works, 125:53-57, 70-72 (1994). *Part Two.* 126:54-56.

Lee, G.F. and Jones-Lee, A. (1996). *Significance of eroded suspended sediment-associated constituents.* Land and Water 40(1):19-23.

Mangarella, P. (1992). *Source identification and control - Santa Clara Valley nonpoint source pollution control program.* Source Identification and Control Report prepared by Woodward-Clyde Consultants, Oakland, CA.

Paulson, C. and Amy, G. (1993). *Regulating metal toxicity in storm water.* Water Environment & Technology, Water Environment Federation, 5:44-49.

Perciasepe, R. (1994). *NPDES watershed strategy.* U.S. Environmental Protection Agency, Office of Water, Memorandum to Water Management Division Directors (Regions I-X), Washington, D.C.